Productivity Improvement in Steering Knuckle Machining Line Using Lean Techniques-A Case Study

M.Ashiq Hyder[1], D.Ranjith[2], R.Jayachitra[3], R.R.Pradeep[4]

[1]*UG Student, Department of Mechanical Engineering, PSG College of Technology, Coimbatore 641004, India*
[2]*UG Student, Department of Mechanical Engineering, PSG College of Technology, Coimbatore 641004, India*
[3]*Assistant Professor, Department of Mechanical Engineering, PSG College of Technology, Coimbatore 641004, India*
[4]*PG Student, Department of Mechanical Engineering, PSG College of Technology, Coimbatore 641004, India*

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Abstract - *In today's competitive manufacturing environment, companies are constantly looking for ways to improve. Because of this, many companies are striving to become "lean" by implementing lean tools, which is a difficult process. Simulation was used to aid in the implementation of lean manufacturing to reduce the trial-and-error period of lean manufacturing and find to optimum approach to implement the lean manufacturing principles. In this research, a case study of implementing level loading of the steering knuckle machining line is examined. To implement level loading, process study of machining line was conducted and bottleneck process was identified. The load on the bottleneck machine whose cycle time was double the Takt time was leveled by sharing the work done by that machine with another machine which having lesser cycle time than the Takt time. The simulation is performed to compare the present and level balanced process. The time and motion study is performed to identify the non-value added activities of workers and non-value added activities are reduced. In order to reduce the motion wastes and unwanted transportation, a new material handling system has been designed and developed.*

Key Words: Value stream mapping, Line balancing, Work study, Gravity Feeder.

1.INTRODUCTION

Customers have numerous choices when it comes to buy their product. Having choices available to the consumer and expectation of shorter order fulfilment lead times, customers have become more fickle in their purchasing decisions and less loyal to their old long-standing business relationships. Products with similar features and price offered by multiple manufacturers begin to approach commodity market. Products can be produced in many ways. They can be manufactured by lean methodology or in batch quantities routed through traditional work centres. It depends on many situations, to choose lean or batch manufacturing such as the quantities, cost, manpower and others. Lean manufacturing is a proven technique that allows work to be performed without bottlenecks or delays. In the lean environment, these activities do not add value to the product and considered a waste. The lean manufacturing methodologies eliminate the wasteful activities by linking and balancing equal amounts of work steps together and enabling products to be consume directly into the next step through the process of one piece at a time until completed. The sum of the work time minus the added queue and wait time required to progress through the manufacturing processes is always shorter than the time required to route products through a batch manufacturing.

2. LITERATURE SURVEY

Abdulmalek and Rajagopal[1] applied lean manufacturing principles to improve a process at a steel mill. Value stream mapping is been used to map the several scenarios. Their paper also described simulation models to explain potential benefits of reduced lead time and reduced WIP inventory. McDonald et.al.[2] have explained wasteful steps that to be eliminated and flow can be introduced in the remaining value-added processes. The concept of flow is to make parts ideally one piece at a time from raw materials to finished goods and to move them one by one to the next workstation with no waiting time in between. K.Hemanand et al. [3] designed and developed the gravity feeder for the material handling system which have been used to reduce the motion and transportation wastes. K.Hemanand et al. [3] identified the problems in the current layout of Bearing cap machining line and analyzed through simulation. Then the layout is modified, simulated and the results are compared with the current layout. Ganesh kumar N et al. [4] have done time and motion study of T-shirt manufacturing process and used two handed process chart to eliminated non-value added activities of workers thereby reducing the cycle time of the process.

3. METHODOLOGY

Unbalanced machining line has been identified and the solution can be obtained by conducting work study on both men and machine and using the lean tools like line balancing etc. The brief methodology of our project is shown in Figure-1.

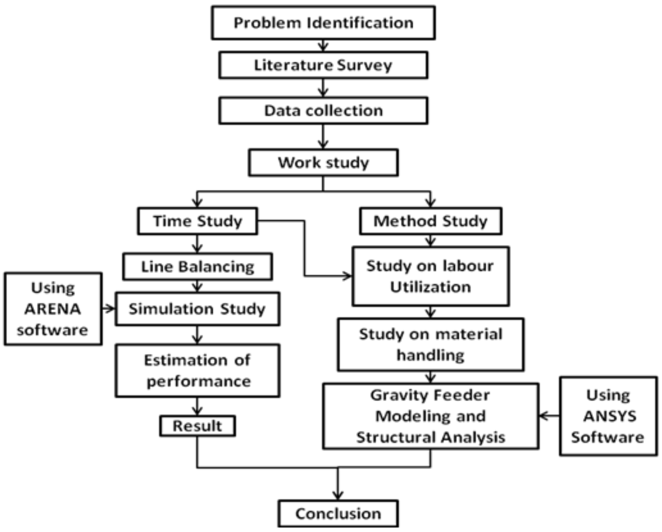

Fig -1: Methodology

4. DATA COLLECTION

The process flow of steering knuckle is given in Figure-2.

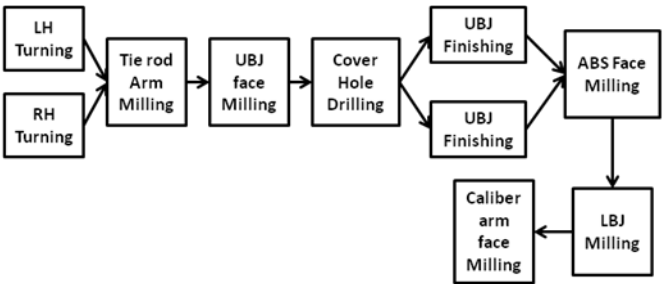

Fig -2: Process Flow

The stop clock approach is employed for observing time for each activities while worker involved in manufacturing the component. The cycle time and worker allocation to each machining process is given in the Table-1. The machines 3, 4, 5, 6& 9 are double palette machines hence their set up times are considered as zero.

Calculation of Takt time:

1)Demand per day =558 components
2)Demand per shift =186 components
3)Available time per shift =420min
4)Takt time = Available time/ Customer demand
=420/186=2.25min=135sec

Table -1: Cycle time for each machining process

S.No	Machine No	Machine type	Operation	Operator No	Machine time(Sec)	Setup time(Sec)	Total Cycle time
1	1	Turning Centre	LH knuckle main bore turning	1	127	17	154
2	2	Turning Centre	RH knuckle main bore turning		135	17	144
3	3	HMC	Tire rod arm milling and taper hole drilling	2	120	0	120
4	4	HMC	UBJ milling & rough boring	3	130	0	130
5	5	HMC	Cover hole drilling and tapping	4	135	0	135
6	6	HMC	UBJ finishing, side milling, chamfering & slitting	5	271	0	271
7	7	HMC	UBJ finishing, side milling, chamfering & slitting		271	17	288
8	8	VMC	ABS face milling, drilling & tapping	6	120	15	135
9	9	VMC	LBJ milling & taper hole drilling	7	135	0	135
10	10	VMC	Caliber arm face milling, drilling & tapping	8	119	15	134

5. LINE BALANCING

The takt time of the machining is found to be 135sec or 2.25 min. Except the machines 3, 6, 7, 8, all other machines having the cycle time closer to the takt time. So these machines are to be balanced to the takt time in-order to facilitate one piece flow and to reduce work in progress inventory and therefore productivity found to be increased.

No of stations required are calculated as follows,

- Total Machining time = 20.295 mins
- No of stations required for line balancing

=Total machining time/Takt time

=20.295/2.25=9 mins

Then 9 stations are required for this line balancing process. The bottleneck machining process is UBJ Finishing process since it has the cycle time of 4.5 min. Though both the machines 6&7 are performing same operation, there is queue of components ahead of these machines. The list of process involved in the machine 6&7 and their respective cycle time are given in the table-2.

Table -2: Bottleneck machining process

S.No	Process	Cycle time(sec)
1	15° Chamfering and ϕ49 mm rough boring	48
2	ϕ49mm fine boring	42
3	Spot facing	42
4	Φ13mm drill	47
5	6.35 mm slitting	48
6	Chamfering	18
7	Slitting bur reamer	26
Total Cycle Time		271

The total number of process taken place in these machines are segregated based on takt time and assigned to machines 6 & 7. The table 3 and 4 shows the process assigned to machines 6 & 7 respectively.

Table -3: Assigned operation to machine 6

S.No	Process	Cycle time(sec)
1	15° Chamfering and ϕ49 mm rough boring	48
2	ϕ49mm fine boring	42
3	Φ13mm drill	47
4	Set up time(Double pallet)	0
Total Cycle Time		137

Table -4: Assigned operation to machine 7

S.No	Process	Cycle time(sec)
1	Spot facing	42
2	6.35 mm slitting	48
3	Chamfering	18
4	Slitting bur reamer	26
5	Setup time	19
Total Cycle Time		153

Even after sharing the tasks machine 7 having cycle time higher than that of takt time is found to be mainly because of its set up time. This machine can further balanced by interchanging its tasks with machine 3 which is a double palette machine and having cycle time (120 sec) lesser than the takt time. Now the balanced cycle time of machine 3 & 7 are given in the table-5 and 6 respectively. The comparison of takt time before and after line balancing is given in Chart-1.

Table -5: Balanced cycle time of machine 3

S.No	Process	Cycle time(sec)
1	Machining Time	120
2	Setup Time	19
Total Cycle Time		139

Table -6: Balanced cycle time of machine 7

S.No	Process	Cycle time(sec)
1	Spot facing	42
2	6.35mm slitting	48
	Chamfering	18
	Slitting bur reamer	26
Total Cycle Time		134

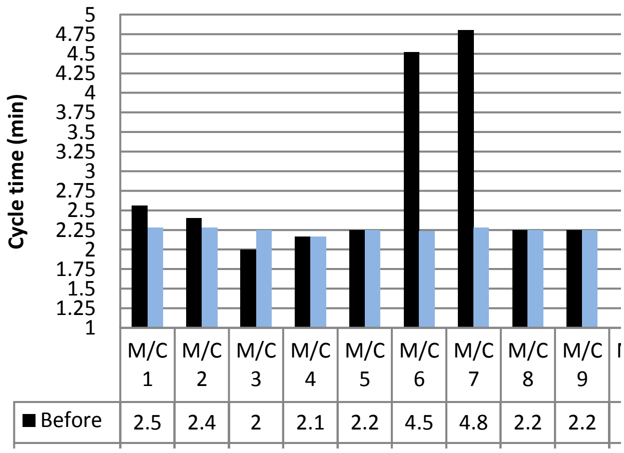

Chart -1: Comparison of takt time before and after line balancing

5. SIMULATION MODEL

To evaluate potential gains based on the implementation of the line balancing, a detailed simulation model was developed using System Modeling Corporation's Arena 5 software. The model for the current system has been developed, which was later modified to model the proposed future state. Before evaluating the future state, considerable effort was expended to verify and validate the model for the current system. Verification is the process that ensures that the simulation model mimics the real system [5]. A detailed animation was used to further verify that the model sufficiently replicated the real system. Validation of the model calls for comparing outputs of the simulation to those from the actual system. Measures that included were inventory at the finishing mill and the total time in the system, with actual data. The simulation model run for a day period, so that the model can be validated when it is in steady state. It should be noted that the figures represent average values. From the table it is clear that the numerical outputs from the simulation are all within the range of the actual data. Simulation is non-terminating, but initial conditions do influence the initial dynamics of the system. Starting with an empty system at time zero, a transient (warm up) period was used for the system to load itself with entities and subsequently reach steady state. The warm up period for our simulation model was established by carrying out ten replications with each having a run length of one shift (480 min). The ten replications examined successive observations of various performance measures. The warm up period is found to be 48 min. Figure-3 shows simulation model of balanced machining line.

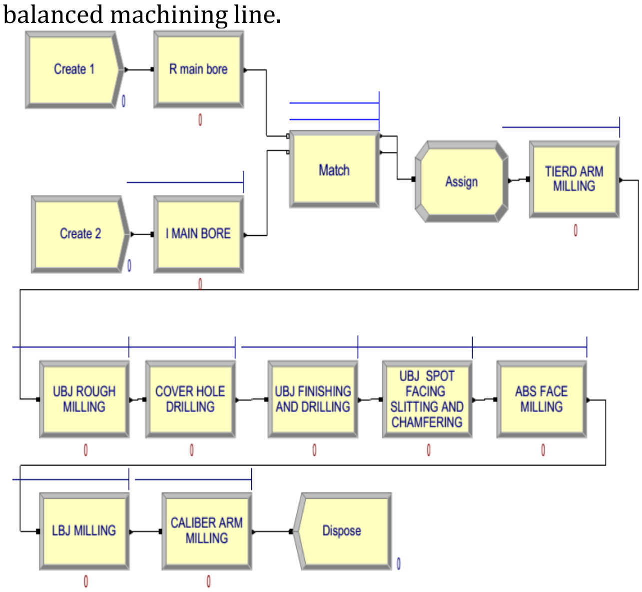

Fig -3: Simulation model of balanced line

5. WORK STUDY

The time and motion study is performed to remove the non-value added activities of worker. The two handed process chart as shown in Figure-4 is drawn to find non value added activities and useful movement of worker. Figure-5 shows value added movement for man 1and man machine chart for man 1 as shown in Figure-6 is drawn to define cycle of operation of worker and to improve their utilization. Similarly the chart is drawn for other operators.

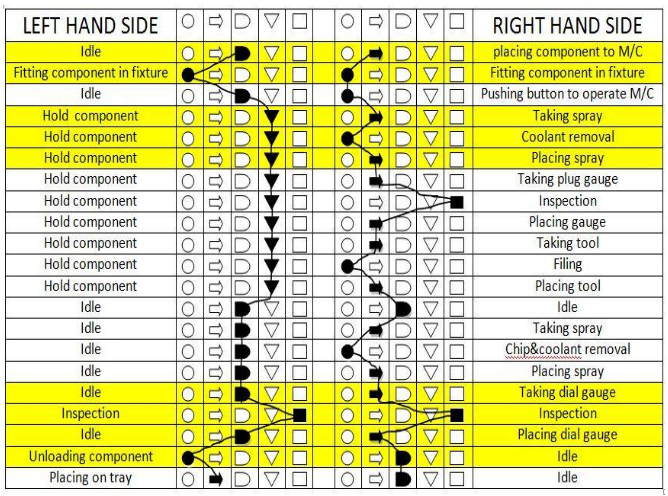

Fig -4: Two handed process chart(Before implementation)

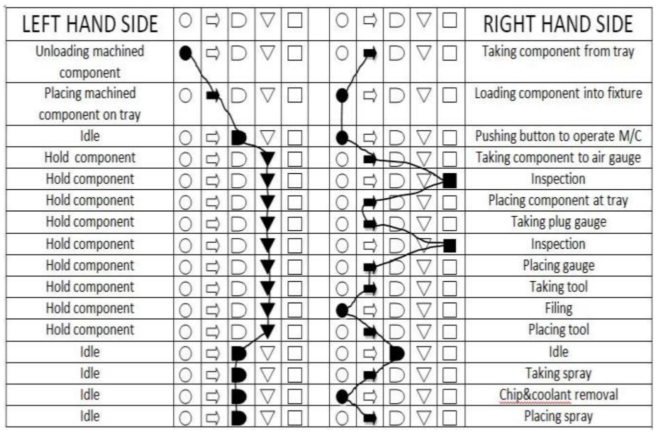

Fig -5: Two handed process chart(After implementation)

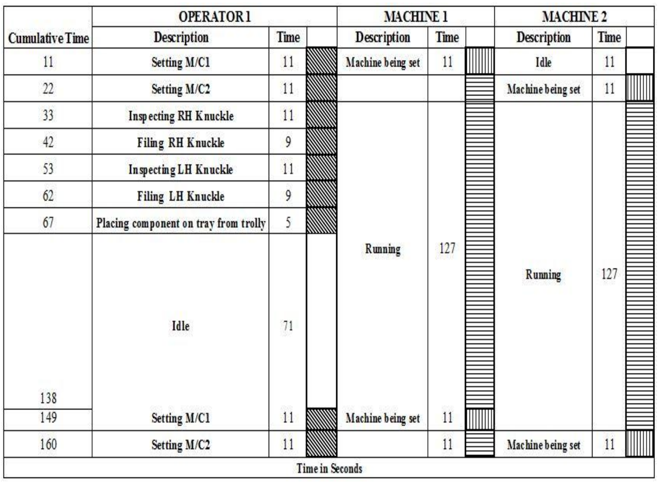

Fig -6: Man machine chart

From the work study, it is observed that 5 operators are sufficient for this machining process. The man-machine chart clearly shows their cycle of operation. The worker utilization before and after the work study are shown in the table-7 and table-8 respectively.

Table -7: Worker utilization (Before)

Operator	1	2	3	4	5	6	7	8
Working time (Sec)	114	40	45	39	150	42	23	62
Idle time(Sec)	30	80	85	96	121	93	112	58
Cycle time(Sec)	144	120	130	135	271	135	135	120
Utilization(%)	79.1	33.6	34.6	28.8	55.3	31.1	17	51.6

Table -8: Worker utilization (After)

Operator	1	2	3	4	5
Working time (Sec)	78	80	77	80	84
Idle time(Sec)	66	69	58	55	51
Cycle time(Sec)	144	149	135	135	135
Utilization(%)	54.16	53	57	59.2	62.3

6. GRAVITY FEEDER DESIGN

The component after machined from Machine 8 is transported to Machine 9 by trolley. In this transportation, Buffer type is followed. Labours spend their idle time for material transportation. And it will increase the fatigue of labour. The transportation of material is shown in Figure-7.

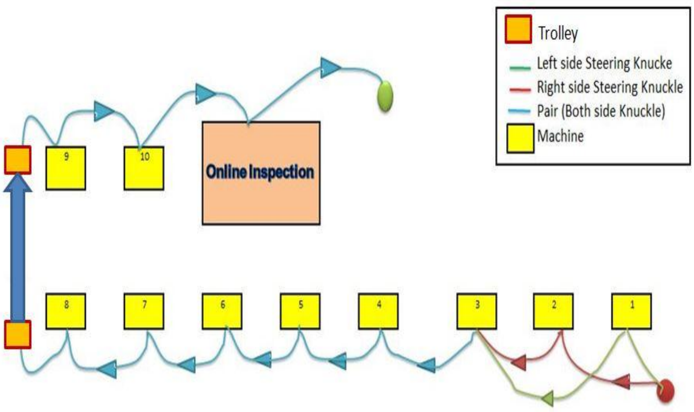

Fig -7: Material Flow

6.1 Design of Material gravity feeder

A gravity operated feeder has been designed for the suitable material handling of steering knuckle. The main aim of this gravity feeder is to reduce material handling time and transportation in between two machines.

The feeder is made up of 3 mm structural steel sheet. The 3D view of the feeder to is shown in Figure-8. This model can carry about 3pairs of steering knuckle per meter in the feeder. The Steering Knuckle weight varies from minimum 7.25kg to maximum of 8kg. So the maximum weight 8 kg is selected.

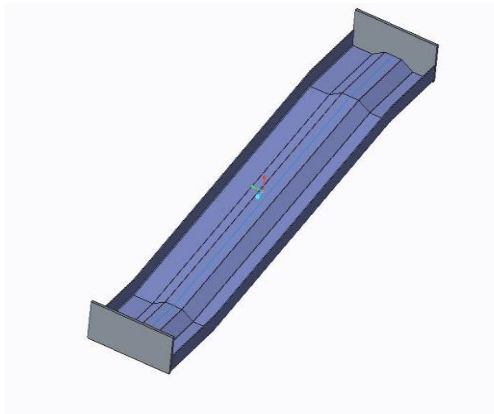

Fig -8: Model of Gravity Feeder.

6.2 Structural Analysis of Feeder

The gravity feeder model is analyzed using ANSYS 15.0 to ensure the design is able to withstand the maximum loading condition .The model is completely meshed with Fine mesh and 5mm is given for element size. The meshing of the feeder model is shown in Figure-9. The Figure-10 shows the deformation of feeder for maximum loading condition. From the analysis, the maximum deformation is found to be 0.0002597mm, which is reasonably negligible. So the design of gravity feeder is safe.

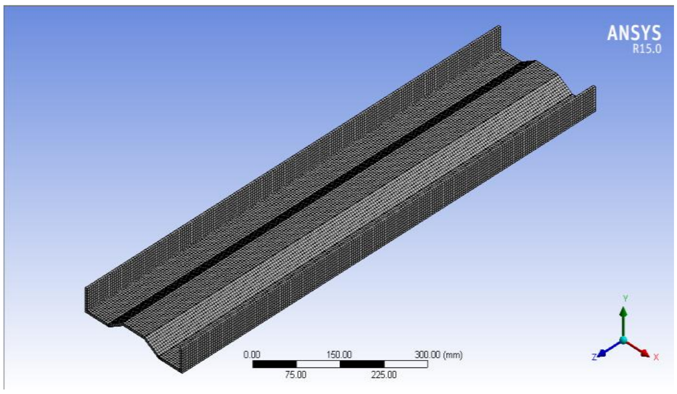

Fig -9: Meshed model

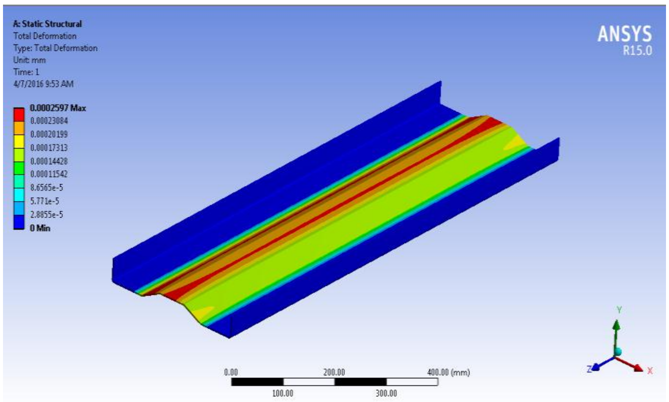

Fig -10: Deformation of gravity feeder

The implementation of gravity feeder in between work stations reduces the motion waste and effort of the labours. It enhances the labour's job satisfaction.

7. RESULTS AND INFERENCE

- Line balancing will increase total number of components per day by 22 from present day production of 468 components.
- Time and motion study reduces 3 workers and improves each worker's utilization by 14%.
- Gravity feeder will reduce the worker's fatigue.

The As-Is analysis of the work is given in the table-9.

Table -9: As-Is analysis

S.No	Contents	Before lean implementation	Expected
1	Production output per day	468	490
2	No of Operators	8	5
3	Lead Time (min)	110	59
4	WIP	33	18

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